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ASD TECHNICAL REPORT 61-270

HUMAN PERFORMANCE AND THE WORK-REST SCHEDULE

W. DEAN CHILES

BEHAVIORAL SCIENCES LABORATORY
AEROSPACE MEDICAL LABORATORY

OSCAR S. ADAMS

LOCKHEED AIRCRAFT CORPORATION

JULY 1961

AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

NOTICES

ASD TR 61-270

Aeronautical Systems Division, Aerospace Medical Laboratory, Wright-Patterson Air Force Base, Ohio

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This report contains a condensation of the material most relevant to the problem of work:rest scheduling in advanced aerospace systems. The major conclusions drawn are: (a) periods of wakefulness longer than 24 hours requiring performance of critical tasks are not feasible as a routine procedure; (b) 6 hours

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FOREWORD

This report was prepared under Project 1710, "Training, and Psychological Stress Aspects of Bioastronautics," Task 71582, "Performance Effects of Environmental Stress," with Dr. W. Dean Chiles acting as task scientist. This review was completed in April 1961. Much of the material contained herein is based on the literature review (ref. 15) carried out by Lockheed Aircraft Corporation, Georgia Division, Marietta, Georgia.

ABSTRACT

This report contains a condensation of the material most relevant to the problem of work:rest scheduling in advanced aerospace systems. The major conclusions drawn are: (a) periods of wakefulness longer than 24 hours requiring performance of critical tasks are not feasible as a routine procedure; (b) 6 hours of sleep per day are adequate for most individuals; (c) sleep periods should not be less than 2 hours in duration; (d) continuous performance of monotonous tasks by themselves should not exceed 2 hours; (e) performance of active tasks may be extended to 10 hours; (f) total cycle duration (work plus rest) should be 4, 6, 8, or 12 hours in order to permit regular day to day schedules; (g) where stress will be high, schedules no more severe than 2-work:2-rest (or equivalent) should be used; (h) 7 or 8 days pretesting should be adequate to select persons adaptable to schedule changes; (i) a 5-day preadaptation period should be used to overcome initial sleep losses.

PUBLICATION REVIEW

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HUMAN PERFORMANCE AND THE WORK-REST SCHEDULE

INTRODUCTION

In recent years, most studies concerned with the length of the work day have supported the reduction of the number of working hours as a means of increasing worker efficiency. However, if total work output is to be maintained, the number of workers has to be increased, and there are some conditions under which personnel cannot be readily added or exchanged. This is the case in those aerospace systems in which (a) weight is a critical problem, (b) projected mission durations exceed 30 hours, and (c) there is a requirement for around-the-clock performance of one or more tasks. This report concerns systems of the type in which a major goal is the maximal utilization of crew personnel to minimize the weight penalty incurred by carrying additional "shifts" of personnel and their associated equipment while at the same time maximizing the probability of mission success. Examples of such systems are: long range (nuclear powered) aerodynamic vehicles, earth orbiting satellites, and space vehicles.

What types of factors can be manipulated to increase the efficiency of crew utilization? First, the provisions for environmental protection, nourishment, etc., are assumed to be adequate to insure the operator's physiological well being, and second, the tasks to be performed by the human operator are assumed to have been reduced to the optimal number through automation. This leaves, then, three additional approaches to increased operator efficiency: equipment design, training, and procedures. The topic to be discussed here is a specific aspect of the third of these factors, namely, the scheduling of work and rest periods.

There are two temporal facets of the work:rest schedule: (a) the length of individual work periods and rest periods and (b) the ratio of the total amount of time at work in a 24-hour period to the total amount of time for rest, sleep, etc. For example, a 1:1 ratio of work and rest could involve 2-hour shifts or it could involve 12-hour shifts.

Let us consider an example. Suppose we have tasks to be performed which require 48 man-hours of work spread more or less evenly over the 24-hour day. Under normal industrial conditions, 6 men would be employed to work as pairs for 8-hour shifts. If the situation were pressing, 4 men might be used to work 12-hour shifts. Under very unusual conditions, 3 men could be used on 16-hour shifts. However, unless the situation were extremely critical, the man would probably not be asked to follow this third schedule for more than 3 or 4 days, following which he would be given 3 or 4 days off. Because of the weight penalty associated with adding extra personnel, in most aerospace systems we are, in effect, faced with an extremely critical situation. Therefore, extreme work:rest schedules must be considered.

In the selection of a specific work:rest cycle, three primary factors must be considered: (a) the amount of sleep required by the man, (b) the nature of the tasks which he is to perform and (c) the levels of proficiency which are demanded. Unfortunately, these factors might well be expected to interact, e.g., the amount of sleep required to perform at a satisfactory level on one type of task is very likely different from that required for other types. In turning to the literature for information, we find that many reports which would appear to be relevant to this problem actually turn out to be of only limited usefulness for one or more of four main reasons: (a) the situations studied did not involve any appreciable restriction on numbers of personnel; (b) the tasks were not representative of those found in aerospace vehicles; (c) the data were not collected in a quantitative form; or (d) no control was exercised over the off-duty activities of the subjects. In this respect, one finds that the industrial literature, most studies of crew performance in both surface and underwater craft, and reports concerning isolated radar sites are not directly applicable to the work:rest problem as conceived here. Thus, although there is a sizeable body of literature which gives us clues as to the operation of these factors considered separately, there are only three studies (refs. 1, 3, and 16) which avoid the limitations just listed to any appreciable degree of satisfaction, and in only one of these three (ref. 1) was the work:rest cycle manipulated as an independent variable.

SLEEP REQUIREMENTS

In most of the studies of sleep requirements the investigators have examined prolonged wakefulness or maximum periods with no sleep rather than the minimum sleep requirements for effective performance over periods of several days. These studies are in general agreement that there are no pronounced performance decrements after periods of up to 100 hours of wakefulness provided the period of performance is quite short. However, a critical observation in such studies is that after 24 to 30 hours of wakefulness, subjects are very difficult to keep awake unless they are forced to be physically active, or the experimenter continually prods them. In other words, for periods greater than 24 hours, forced wakefulness for the performance of critical tasks is not feasible as a routine procedure.

Considering the question of minimum sleep requirements, in one study subjects were permitted to sleep 3 hours, were kept awake 3 hours, slept 3 hours, and then stayed awake for 15 hours over a period of one month (ref. 8). With this schedule no decrements were observed in the performance of psychological tasks. This sort of data, along with every day experience, suggests that for most people 6 hours of sleep per day are adequate, and sleep periods should not be shorter than 2 hours to allow for time to go to sleep.

DUTY PERIOD DURATION

The primary factor involved in the selection of appropriate duty periods is the nature of the activity required of the man. On one hand, we have tasks which involve passive performance on the part of the individual, in that he may sit for several minutes waiting for an event that happens at a very low average rate; this sort of task is exemplified in radar watchkeeping. On the other hand, we have tasks that require active participation of the operator in more or less continually taking actions of some sort, e.g., manual control of an aircraft under instrument conditions. Most tasks, of course, lie somewhere between these two extremes.

We will consider passive tasks first. On a particular laboratory simulation of a radar watchkeeping task, signals were presented on an average of every 2 minutes. Decrements in the accuracy of detection of signals occurred as early as 30 minutes after the beginning of the test period (ref. 9). However, such decrements can usually be prevented, or original levels regained, by introducing any distraction that would tend to relieve monotony. For example, in a long term study (ref. 6), decrements were found in the performance of one passive task presented by itself but not in that of another which was combined with an active task. In another long term study (ref. 1), the results suggested that subjects who followed a 2:2 or 4:4 schedule did relatively better on monitoring tasks (which are passive in nature) than did subjects who followed an 8:8 schedule. The 2:2 and 4:4 subjects also seemed to make a better overall adjustment to what was a very boring situation.

Turning to active tasks, it has been amply demonstrated in the industrial situation that when the worker has control over his rate of activity, the production rate per hour will increase if the length of the work day is decreased from 12 or 10 hours per day to 8 hours (ref. 7). In addition, very valuable related gains are realized through decreases in accident rates and absenteeism. One of the general conclusions reached is that the man in such situations works at a near maximum rate for a period; he then takes either an unofficial or official "rest break," after which he resumes his original rate of output. Because of these breaks, the period of continuous duty in most industrial jobs usually turns out to be about 2 hours and is seldom longer than 4 hours because of lunch breaks. Of more direct relevance to our problem are studies which have measured flying proficiency during long instrument flights (ref. 14) and navigator activity during extended arctic missions (ref. 4); these studies suggest that the man may lower his performance standards toward the end of a 12- to 17-hour flight. In addition, investigations of several types of skills in truck drivers following 10 hours of driving have demonstrated decreases in efficiency on factors, such as reaction coordination, reaction time, manual steadiness, and driving vigilance (ref. 10).

On the basis of these and similar studies, we recommend that the maximum duty period be 4 hours when (a) a passive task is combined with one or more active tasks (b) the work load is not too great and (c) a high level of performance must be maintained continuously. When a passive task occurs by itself, a 2-hour maximum is advisable. When the major tasks call for active participation, when there is considerable variety in the tasks, and when any passive tasks have very readily detectable signals to which the operator must respond, the duty period may be routinely extended to 10 hours. Duty periods that require relatively continuous performance for longer than 10 hours are likely to require crewmembers to exert increasing effort to avoid lowering performance standards; and, thus, any lapse in effort would decrease the probability of mission success.

LONG TERM PERFORMANCE

There has been only one series of studies in which the work-rest cycle and work:rest ratio have been varied systematically. In the first study in this series (ref. 1) 96 hours of performance on four different cycles--2:2, 4:4, 6:6, and 8:8--were examined. The shorter cycles, 2:2, and 4:4, were preferred by most subjects, and there was a suggestion that prolongation of the 6:6 and 8:8 cycles would lead to decrements because of the boredom induced by the tasks.

This first study was followed by two additional 96-hour experiments, one with a 4:2 schedule and one with a 6:2 schedule. Although the performance data did not indicate that the 4:2 schedule was superior, the questionnaire data and especially the amount of sleep which subjects were able to get suggested that severe decrements would probably result from prolonging the experimental period in the case of the 6:2 schedule, but probably not in in the case of the 4:2 schedule.

In the final study of this series, operational personnel (two B-52 crews) were tested on a 4:2 schedule over a 360-hour (15 day) period while confined to a simulated crew compartment. Under these conditions 3 men with appropriate cross training cover 2 positions continuously. The primary results of this study were that (a) individual subjects showed considerable variability in the course of a day's performance; (b) there were wide differences among the performance levels of different subjects; and (c) some subjects showed continued improvement over the entire 15 days of confinement. The general conclusion drawn from this series of studies is that, with a minimum amount of selection, highly motivated subjects can be found who will maintain acceptable performance levels on a 4:2 schedule for periods as long as 15 days and probably for 30 days.

Two additional studies are relevant to this problem. In the first of these (ref. 17), 4 subjects individually followed a 4:4 schedule while confined for a 7-day period to a one-man "space cabin simulator." Three of these subjects showed essentially no decrements in performance over the 7-day period, but the fourth showed very erratic performance with decrements occurring daily. In another study (ref. 3) 6 subjects were confined for an 8-day period to a simulated crew compartment. In this study each man was on duty for a total of 11 hours and off for a total of 13 hours; two 4-hour sleep periods, separated by 8 hours, were permitted each 24 hours. No marked deterioration in performance was observed.

Certain other factors should be considered in selecting a work:rest schedule for long term performance. First, because of man's propensity for developing "natural"24-hour cycles, care should be taken to permit him to develop new ones if a non-normal schedule is to be followed. Kleitman (refs. 11 and 13) found evidence of adaptation of men to 18- and 28-hour days after about 9 weeks. On the other hand Brindley (ref. 2) was unable to find evidence of complete adaptation to a 22-hour day after 8 weeks. In studies of Naval personnel on submarine duty, Kleitman (ref. 12) found complete adaptation to a 12-hour cycle which, with respect to a 24-hour day, permitted consistent daily scheduling of sleeping and alimentary processes. This suggests that the total cycle duration (work plus rest) should permit regular daily schedules, i.e., the total cycle duration should be 4, 6, 8, or 12 hours. Second if the levels of psychological stress would be expected to seriously interfere with sleeping or if physiological tolerance limits may be routinely in danger of compromise, schedules no more severe than 2:2 or 4:4 should be used. Third, pretesting for a 7- or 8-day period in an appropriate simulator should eliminate those individuals who are unable to adapt to altered diurnal schedules. Fourth, the shift from a normal schedule would usually be expected to result in an initial period of sleep loss for approximately the first 4 days; therefore, a 5-day preadaptation period on a given schedule should be used.

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